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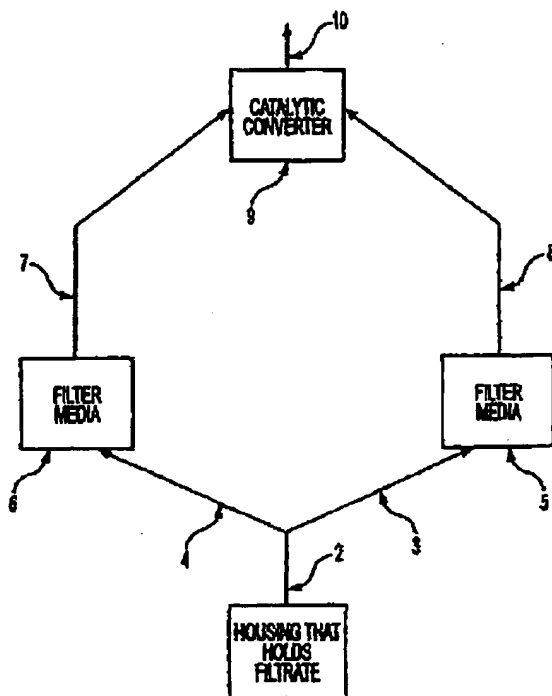
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(54) Title: **FILTRATION MEDIA OF POROUS INORGANIC PARTICLES**

(57) Abstract: Inorganic, porous particles filter a substance or substances from a flow of fluid such as a gas. The particles can be arranged into a bed to filter a substance (filtrate substance) from a fluid. The filtrate substance can collect on or within the pores of the inorganic particles. Collection of the filtrate substance within the pores of the particles rather than within the interstices of the bed enhances the filtering capacity and does not impede the flow of fluid through the bed of particles. Furthermore, the inorganic particles are re-usable, in that they can be subjected to harsh filtrate-separation techniques, e.g., heat treatment, solvent extraction, detergent washing, and centrifugal separation, yet retain their desired properties.

WO 02/070105 A2

**WO 02/070105 A2**

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WO 02/070105

PCT/US02/05753

## **FILTRATION MEDIA OF POROUS INORGANIC PARTICLES**

### **CROSS-REFERENCE TO RELATED PATENT APPLICATIONS**

This application claims priority to Provisional Application No. 60/272,044 filed March 1, 2001, which is incorporated by reference in its entirety.

### **FIELD OF THE INVENTION**

[0001] The invention relates generally to filtration. More specifically, the invention relates to the use of porous inorganic particles in a filtration apparatus, such as a packed bed, where the apparatus includes porous, inorganic particles. The invention also contemplates the use of the porous, inorganic particles, particularly in a packed bed, which are capable of filtering one or more substances from a fluid, such as air.

### **BACKGROUND OF THE INVENTION**

[0002] Filtration media can be used to prevent undesirable vapors, particulate, or suspended droplets in a gas stream from escaping into the atmosphere. For example, whenever an oleo material or substances (*e.g.* grease, oil or fat) are heated, some will vaporize or form droplets. There is a desire to prevent such vaporized or droplet material from escaping into the air, unfiltered. Presently employed filtering media can include an aggregate of fibrous material, such as organic fiber mat or inorganic fiberglass, that extend over the travelling path of a vapor or liquid, such that the fibrous material catches the oleo vapors or droplets as they pass through the interstices of the filtering material. Although, initially, such filtering mechanisms may be capable of efficiently removing the oleo vapors or droplets from the air stream, the oleo vapors or droplets gather

WO 02/070105

PCT/US02/05753

in the interstices of the filtering material in increasing quantities as the filtration process progresses, resisting the flow.

[0003] The flow rate of air through the filter immediately begins to decrease as the oleo material begins to collect on the filter media. This build-up of undesirable substances can substantially or completely block the flow of air and its load of material to be filtered through the filter, requiring frequent replacement of the filter. This replacement process typically requires a shut down of the mechanism that produces the vapor. Often times, the filter, upon having the undesirable substance collected thereon is disposed of without further use.

[0004] U.S. Patent No. 5,776,354, issued to van der Meer *et al.*, discloses a method for separating a dispersed liquid phase (*i.e.* an oil film) from a gas, using a filter bed of a particulate, porous polymer material whose size is on the order of 0.1 to 10 mm. Although van der Meer *et al.* teach that the dispersed liquid phase can fill into the pores of the particulate material, the particulate material is a polymer, thereby restricting the available methods for subsequently separating the liquid phase from the particulate material. In fact, van der Meer *et al.* only teach centrifugal force (*i.e.* a centrifuge) for separating the oil from particulate material. Thus, there remains need for filtration media that not only (1) ameliorate the problem of restricted airflow through the filter, but (2) also can undergo harsher filtrate-separation processes, yet subsequently retain its desired properties for repeated use.

#### **SUMMARY OF THE INVENTION**

[0005] Accordingly, it is an object of the invention to provide renewable, porous filtering media to separate a filtrate substance (in the form of vapor, aerosol, and/or liquid) from a fluid such as a gas or liquid, such that the flow of the fluid through the porous filtering media will not

WO 02/070105

PCT/US02/05753

be substantially impeded prior to the time said porous media are filled with said vapor, aerosol, and/or liquid.

[0006] It is a further object of the invention to provide filtering media that can retain their filtering properties subsequent to undergoing a harsh filtrate-separation protocol.

[0007] It is another object of the invention to provide filtering media that permit a continuous, uninterrupted fluid flow. This provides a uniform filtration mode until the media are saturated:

[0008] The invention provides for a filtration media that includes porous particles (whose composition is inorganic) arranged to separate one or more filtrate substances from a fluid or fluids wherein the porous particles collect and retain within themselves the filtrate substance(s). In a preferred embodiment, the porous particles are arranged in a packed bed. In a particularly preferred embodiment, the particles relinquish substantially all of the substances during a separation step and the particles maintain the ability to collect the substance(s) repeatedly.

[0009] The invention further contemplates an apparatus for separating one or more substances from a moving fluid which includes a housing for said packed bed of porous particles located in a duct through which said moving fluid with the filtrate substance(s) is passing. Various designs may be used so as to cycle the moving fluid through a plurality of such housings and beds without having to shut down the system. Further, the beds may be treated in said cycles so as to refresh the particles for their intended use.

[0010] In a preferred embodiment, the invention describes a method for substantially separating one or more oleo substance(s) from a fluid, particularly a gas such as air, which comprises the steps of placing the inorganic, porous particles, which may be spherical or pellet-like in shape or have other shapes, into contact with the fluid, which moves relative to

WO 02/070105

PCT/US02/05753

the particles; and allowing the oleo substance(s) to collect within at least a portion of the inorganic particles as the vapor composition passes at least substantially through the inorganic porous particles. In one sense, the inorganic porous particles are arranged to form a network, such as a packed bed, suitable for filtering the oleo substance(s) from the moving fluid.

**[0011]** Methods according to the invention further comprise substantially separating the filtrate substance from the inorganic, porous particles and repeating the steps of placing the inorganic, porous particles into contact with the fluid and allowing the filtrate substance to collect within at least a portion of the inorganic particles.

**[0012]** In another embodiment, the filtrate substance includes hydrophilic vapors or suspended droplets. This invention provides a method for substantially separating the hydrophilic vapors or suspended droplets by placing the inorganic, porous particles, preferably in the form of a packed bed, into contact with a fluid flow which contains the filtrate substance. This allows the hydrophilic substance to collect within at least a portion of the inorganic particles due to the hydrophilic nature of internal and external surfaces of the porous particles. Further, the internal surfaces of the pores of said particles may be treated with reactive substances that may be biocidal, catalytic, or chemically reactive with the contents of said vapors or suspended droplets.

**[0013]** These and other objects will be apparent to a skilled worker, as shown by the embodiments described and contemplated herein.

#### **BRIEF DESCRIPTION OF THE DRAWINGS**

**[0014]** Fig. 1 shows a filtration apparatus comprising a packed bed of inorganic particles and a ventilation system according to one embodiment of the present invention.

WO 02/070105

PCT/US02/05753

[0015] Figs. 2A-2D show a filtration apparatus comprising a packed bed of inorganic particles and a ventilation system according to another embodiment of the present invention.

#### **DESCRIPTION OF THE PREFERRED EMBODIMENTS**

[0016] The present invention provides, *inter alia*, inorganic, porous particles that are capable of trapping filtrate substances from a fluid. As used herein, "filtrate substance" is defined as the substance (e.g., gas, vapor, liquid, suspended droplets, etc.) that is intended to be removed from the fluid. The fluid containing the filtrate substance can be either a gas or liquid.

[0017] The particles are suitable for separating one or more of the filtrate substances from a fluid flow, e.g. a gas, which contains such filtrate substances. To this end, in a preferred embodiment, the inorganic particles can be arranged into a packed bed-like formation, or network, such that the network comprises (1) particles interacting with each other and (2) interstices defined between the exterior surface area of the interacting particles. Thus, in one embodiment, a fluid containing the filtrate substances can flow through (or substantially through) the packed bed, leaving behind one or more filtrate substances that collect within at least a portion of the particles. Although the embodiments described herein indicate that the fluid moves relative to the filter media, other embodiments such as those in which the filter media move are also contemplated.

[0018] A particularly preferred combination is one in which the filtrate substance is a grease, fat or oil (collectively referred to as an "oleo substance") and the fluid is air.

[0019] As indicated, the inorganic particles, or media, that comprise the core of the filtration apparatus described more fully below, are porous, having an external surface area and a network of open channels that



WO 02/070105

PCT/US02/05753

define internal surfaces. In a preferred embodiment, the inorganic particles can have any suitable shape, e.g., spherical, pellet-like, etc. The particles may have any suitable size depending on end use, and may range in size from about 0.25-4 mm, preferably 0.33-3.5 mm, and more preferably 0.5-3 mm. For non-spherical particles, the size measurement is taken at the largest dimension. In other suitable embodiments, the particles can have a size that ranges from greater than 4 mm, preferably from greater than 4 to 50 or even 100 mm. In some embodiments, the pores preferably have a mean size between about 0.01 to 100 microns, preferably 0.1 to 10 microns. The media can also have other shapes such as porous fibers and other formed shapes such as rings, saddles, etc.

[0020] The inorganic particles can have porosity in the range of 15-70%, preferably 30-70%. These internal surfaces accordingly are exposed to the filtrate substance (e.g. oleo) substance(s) passing through the network of particles. That is, the pores of the inorganic particle or particles are large enough such that the filtrate substance can fit inside of, or otherwise pass through, one or more pores. Accordingly, in one embodiment, the surfaces of the pores can comprise an oleophilic substance and, therefore, attract an oleo substance. In this sense, a relatively powerful force, such as surface tension, can draw the filtrate substance within the openings of the pores. Hence, the filtrate substance, such as an oleo substance, can collect within the pores in lieu of and/or in addition to adhering to the exterior surface area of the particles. In other embodiments, described more fully below, the interior and/or exterior of the particle can have a catalyst and/or reactant coated thereon.

[0021] The open channels, e.g., pores, of the inorganic particle in a preferred embodiment can exist in a reticulated, open, sintered structure. In this sense, a reticulated structure is a structure made up of a network

WO 02/070105

PCT/US02/05153

of interconnected struts that form a strong, interconnected continuum of pores. A method for preparing a sinterable structure is disclosed in co-pending application Serial No. 09/286,919, entitled "Sinterable Structures and Method", which is hereby incorporated herein by reference in its entirety. More specifically, this co-pending application describes processes for producing a porous, sintered structure, comprising (1) preparing a viscous mixture comprising a sinterable powder of ceramic or metal dispersed in a sol of a polymer in a primary solvent; (2) replacing the primary solvent with a secondary liquid in which the polymer is insoluble, thereby producing a gel which comprises an open polymeric network that has the sinterable powder arranged therein; (3) removing the secondary liquid from the gel; and (4) sintering the sinterable powder to form the open, porous structure.

[0022] The particles of the invention may be comprised of any inorganic material that confers the requisite characteristics upon the particles (e.g. capable of containing pores, at least substantially maintains porosity and ability to collect a filtrate substance inside the pores of the particles after a filtrate-separation operation describe more fully below, preferably a harsh filtrate separation). An illustrative list of suitable materials of which the particles can be comprised include: a ceramic material such as transition metal oxides, zircon, zirconia, titania, silica, alumina, alumina-silica (clay) or a variable blend thereof. An especially preferred particle is a clay such as kaolin, bentonite or montmorillonite. Porous iron made by 09/286/919 also will absorb oleo substances.

[0023] The individual porous particles, once formed, can be assembled into a network suitable for filtering the one or more substances from the fluid composition. The porous particles can be arranged as a packed bed in a vertical plane, a horizontal plane or both. Preferably, each porous particle interacts with at least one other particle, yet forms interstices

WO 02/070105

PCT/US82/05753

between the particles, such that a fluid can pass through the interstices. In one embodiment, the porous particles form a bed that defines a constant surface area. The particles preferably extend along at least the horizontal or vertical cross section of the bed or casing to define a continuous section of alternating particles and interstices. An example is a bed of porous particles packed within a perforated or porous wall container. Alternatively, two or more particles of the bed may be physically attached, such as by heating the particles to sufficient temperature to sinter the particles together, while maintaining space between the particles sufficient to allow the passage of a vapor or liquid there through.

[0024] Once formed, the inorganic porous particles, which can be in the form of the network described above, can be placed into contact with a fluid composition containing the filtrate substance, preferably an oleo substance. The particles may be positioned in association with a fluid such that the fluid passes through or at least substantially through the interstices and/or pores of inorganic particles, leaving behind at least a portion, but preferably the majority, of the filtrate substance suspended in the fluid. In this sense, the filtrate substance collects on and within the inorganic particles.

[0025] As the fluid passes through the packed bed of inorganic particles, there is resistance to the flow, resulting in a drop in pressure on the exit side of the bed. In a preferred embodiment, this drop in pressure remains substantially constant, which means that the filtrate substance collect within the pores to a greater extent than in the interstices between the exterior surface area of the particles. At any time, the inorganic particles can be removed from the flow of fluid, in order to separate the filtrate substance from inorganic particles. In some embodiments, the particles may be regenerated, *in situ*. However, it is preferred that the

WO 02/078105

PCT/US92/05753

particles are removed from the fluid flow whenever the filtrate substance at least substantially has filled the pores and/or may have begun to fill the interstices between the inorganic particles. This conveniently can be determined by detecting a measurable decrease in the pressure of the fluid through the filter media.

[0026] The inorganic particles may be removed from the fluid flow in any number of ways, from simple replacement to automated systems. For instance, the particles can be a magnetic material and an external magnetic force may be applied to draw the particles away from the fluid flow, such as vapor flow. Alternatively, gravitational forces could be employed to move the particles downwardly, for example, beneath the fluid flow. In addition, a vacuum force could be used to pull the particles out of the stream of flowing fluid. Further still, the invention contemplates the employment of a see-saw apparatus that has the filter media on both ends of a pivoting elongated member, where the media can be raised and lowered from a filtering position to a regeneration position. In a similar manner, a rotating wheel or disk containing the filtering media can be rotated from a position of filtering to a position of separation and/or regeneration.

[0027] The separation step preferably is carried out such that, upon removing the filtrate substance from the inorganic materials, the inorganic particles again can be used to filter a substance from a moving stream of fluid as before. Filtrate-separation operations may be selected from the group consisting of heat treatment at a temperature sufficient to volatilize the filtrate substances and burn off any remaining residue (up to 1000°C), solvent extraction, detergent wash, and centrifugal removal, and combinations of these separations. Particularly preferred separation operations are harsh filtrate separations such as heat treatment and solvent extraction. Suitable solvents for removing the filtrate substance

WO 02/070105

PCT/US02/05753

may include organic solvents or preferably known biodegradable solvents. A detergent suitable for the detergent washing step can be a commercial one, e.g., Dawn. Other known suitable detergents can also be used. A significant advantage of the present invention is that the inorganic porous particles are capable of withstanding harsh separation treatments where necessary as described above. After the filtrate substance is removed from the inorganic particles, the filtrate substance may be discarded and the particles can be re-positioned within the stream of the flowing fluid. The filtrate collection and separation process can be repeated multiple times.

**[0028]** In the catalytic embodiment, described below, the separation step can be facilitated by incorporation of the catalyst. Because the internal pores are completely available in the sintered structure of 09/285,919, a catalyst coated on the pore walls substantially increases the catalyst availability to reactants, e.g. hydrocarbons and oxygen.

**[0029]** In another embodiment, for instance, porous particles of the invention could contain hydrophilic surfaces within the porous area. The invention, accordingly, contemplates the removal of malodorous or toxic vapors from air. Current filtration apparatus in air conditioning systems, for example, might not effectively remove harmful vapors or droplets, such as those carrying spores or bacteria, e.g. the so-called "Legionnaire's Disease." A porous filter, as described herein, having surfaces adapted to be hydrophilic, could capture noxious vapors or droplets. Thereafter, the trapped vapors or droplets could be heated, thereby destroying any bacteria, spores, virus or other harmful material associated with the vapors or droplets. In a preferred embodiment, the surfaces of the pores, such as struts, can be coated or impregnated with a biocidal agent, such as well known silver containing biocides, e.g., silver iodide and/or antibiotics, e.g., tetracycline. Another possible coating could include

WO 02/070105

PCT/US02/05753

diazoniumdiolate in a siloxane polymer. Of course, the exterior surface of the porous particles can also be coated or impregnated with a biocidal agent.

**[0030]** In still another embodiment, the filtrate substance is treated and subsequently removed by reacting the filtrate substance using a catalyst that is within the pores and on the exterior surface of the particles.

Optionally, the filtrate substance can be reacted with another component that may be coated on the particle, in the fluid, or even the fluid itself. In one embodiment, ethane can be reacted in and subsequently removed from a gas stream by converting the ethane to ethylene in the presence of hydrogen using a noble metal catalyst on the surface and within the pores of the particles. This catalytic reaction can occur by passing the fluid over or through a bed of the inorganic particles, or within a fluidized bed of the same particles.

**[0031]** The invention also provides an apparatus for substantially separating one or more filtrate substances from a moving fluid stream. This apparatus may comprise a packed bed or network of inorganic particles, as described, in combination with a series of vents or ducts that channel the fluid stream towards the network of inorganic particles. The system also may comprise a series of vents or ducts that channel the fluid to another location, upon passing through the network of inorganic particles. For instance, the fluid may exit into the atmosphere upon passing through the inorganic particles. Alternatively, the fluid first may pass through a catalyst bed for further treatment of the fluid.

**[0032]** The system can be constructed such that the source creating the fluid flow does not need to be turned off in order to perform the filtrate substance removing step. To this end, the system may comprise multiple series of ducts or vents that can be operated in tandem with each other. Accordingly, one series of ducts or vents may be opened,

WO 02/070105

PCT/US02/05753

while the others are closed. The open series would act to direct the fluid, such as a vapor, to the inorganic particles and then away from the particles after passing there through. At the appropriate time, the inorganic particles, having the filtrate substance collected therein, can be cleaned by a filtrate-separation protocol, for example. Further, the inorganic particles may remain substantially at their present location or they may be moved to a different location (e.g. by magnetic, vacuum or gravitational force) before separating the filtrate substance(s) from the particles. At this stage, the open series of vents or ducts can be closed and the closed series then can be opened, as the filtering process continues.

[0033] One non-limiting example of a filtration apparatus contemplated by the invention is described in the schematic diagram of Figure 1. With reference to Figure 1, housing (1) holds the filtrate substance, e.g., an oleo substance. Upon being heated within the housing, the filtrate substance in a fluid (in this instance in a stream of flowing exhaust air) enters duct (2). The filtrate substance can then be selectively passed into duct (3) or (4), such as by a valve. The filtrate substance enters the filter media (5) or (6), that includes the network of inorganic particles. A pre-filter (not shown) may be positioned before the filter media.

[0034] The filtrate substance collects within interstices and pores of the particles (not shown), as the exhaust passes through the filter media. Thereafter, the exhaust passes into and through ducts (7) or (8) which lead to catalytic reactor (9). After passing through catalytic reactor (9), the exhaust can be vented into the atmosphere (10).

[0035] The filter media can be positioned adjacent to electric heater (not shown), that, when activated, can transfer heat to particles in the filter media. The heat will cause the filtrate substance, such as an oleo substance (not pictured) to separate from the particles that can be drained

WO 02/070105

PCT/US02/05753

as needed. Generally, the heat-separation process occurs when the apparatus is shut down, or when the fluid flow directed into the other filter media.

[0036] Another embodiment is shown in connection with Figures 2A-2D. With reference to Figure 2A, housing (11) holds the filtrate substance, e.g., an oleo substance. Upon being heated within the housing, the filtrate substance enters duct (12). The filtrate substance then enters into filter media (16). Figure 2D shows the cross section of filter media 16 taken along line I-I. In an embodiment shown in Figure 2B, the filtrate substance can then be selectively passed into duct (14) or (15), such as by a valve (13), and then enter the filter media (16) or (17), that includes the network of inorganic particles. A pre-filter (not shown) may be positioned before the filter media.

[0037] Thereafter, in the embodiment of Figures 2A and 2B, the exhaust gas passes into fan (18) and is vented into the atmosphere through vent (19). In the embodiment shown in Figure 2C, the exhaust first passes into catalytic reactor (20) before passing into fan (18).

[0038] Additional advantages, features and modifications will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details, and representative devices, shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.

[0039] As used herein and in the following claims, articles such as "the," "a" and "an" can connote the singular or plural. All documents referred to herein are specifically incorporated herein by reference in their entireties.



WO 02/070105

PCT/US02/05753

## WHAT IS CLAIMED IS:

1. A method for substantially separating one or more filtrate substances from a fluid comprising the steps of: (a) placing inorganic, porous particles into contact with said fluid moving relative to the particles; and (b) allowing or causing the filtrate substance(s) to collect within at least a portion of said porous, inorganic particles as the fluid passes at least substantially through said inorganic, porous particles.
2. A method according to claim 1, wherein said inorganic, porous particles are arranged to form a network suitable for filtering one or more filtrate substances from the fluid.
3. A method according to claim 2, further comprising isolating said inorganic, porous particles from the fluid after collection occurs.
4. A method according to claim 3, further comprising substantially removing or cleaning the filtrate substance from the inorganic, porous particles.
5. A method according to claim 4, wherein after said separation step, said inorganic, porous particles again are subject to steps (a) and (b).
6. A method according to claim 5, wherein said separation step is selected from the group consisting of heat treatment, solvent extraction, detergent washing, centrifugal separation step and combinations thereof.
7. A method according to claim 1, wherein a dimension of a single inorganic, porous particle is on the order of 0.1-4 mm.
8. A method according to claim 1, wherein a dimension of a single inorganic, porous particle is on the order of greater than 4 to 100 mm.
9. A method according to claim 1, wherein the filtrate substance is an oleo substance and the moving fluid is air.

WO 02/070105

PCT/US02/05753

10. A method according to claim 1, wherein the inorganic, porous particles are spherical, pellet or pellet-like in shape or a combination thereof.
11. A method for substantially separating one or more filtrate substances from a fluid comprising the steps of: (a) placing a bed of inorganic, porous particles into contact with said fluid moving relative to the particles; and (b) allowing or causing the one or more filtrate substances to collect within at least a portion of said inorganic, porous particles as the fluid passes at least substantially through said bed of inorganic, porous particles.
12. A method according to claim 11, wherein during step (b), the drop in pressure of the fluid passing through said bed remains substantially constant for a period of time.
13. A method according to claim 1, wherein the one or more filtrate substances include a hydrophilic substance and the inorganic, porous particles contain hydrophilic surfaces within the porous area thereof.
14. A method according to claim 13, wherein the surfaces of the inorganic, porous particles and pores are coated or impregnated with a biocidal agent.
15. A method according to claim 1, wherein the surfaces of the pores within the inorganic, porous particles are coated with a catalyst.
16. A method according to claim 1, wherein the surfaces of the pores within the inorganic, porous particles are coated with a reactive chemical.
17. A filtration media comprising a bed of inorganic, porous particles arranged to separate one or more filtrate substances from a moving fluid wherein said particles absorb said one or more filtrate substances.
18. A filtration media according to claim 17, wherein said inorganic, porous particles relinquish substantially all of said one or more filtrate substances upon subjecting the inorganic, porous particles to a separation step, and wherein the

WO 02/070105

PCT/US02/05753

inorganic, porous particles maintain the ability to absorb said one or more filtrate substances after said separation step occurs.

19. A filtration media according to claim 18, wherein the separation step is selected from the group consisting of heat treatment, solvent extraction, detergent washing, centrifugal separation and combinations thereof.

20. A filtration media according to claim 17, wherein a dimension of a single inorganic, porous particle is on the order of 0.1-4 mm.

21. A filtration media according to claim 17, wherein a dimension of a single inorganic, porous particle is on the order of greater than 4 to 100 mm.

22. A filtration media according to claim 17, wherein the inorganic, porous particles are spherical, pellet or pellet-like in shape or a combination thereof.

23. A filtration media according to claim 17, wherein the one or more filtrate substances include one or more oleo substances.

24. A filtration media according to claim 17, wherein the inorganic, porous particles are ceramic.

25. A filtration media according to claim 17, wherein the inorganic, porous particles are metal.

26. An apparatus for substantially separating one or more filtrate substances from a moving fluid comprising the filtration media of claim 17, a duct positioned in relationship with the packed bed of porous particles, wherein the moving fluid passes through said duct before passing through said bed.

27. An apparatus according to claim 26, further comprising a catalytic reactor, wherein the fluid passes through the catalytic reactor after passing through the packed bed.

WO 02/070105

PCT/US02/05753

28. An apparatus according to claim 27, further comprising a second duct or an extension of the first duct which joins the catalytic reactor and the packed bed.

29. A method for substantially separating one or more filtrate substances from a fluid, comprising fluidizing a group of inorganic porous particles with said fluid and allowing said filtrate substances within said particles.

WO 02/070105

PCT/US02/05753

1/2

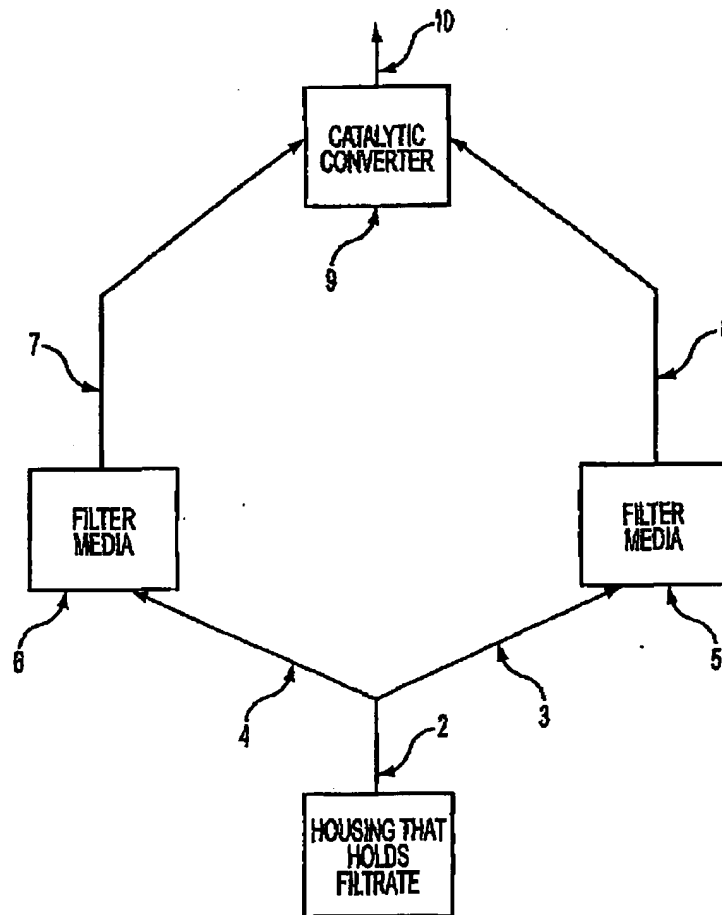


FIG. 1

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WO 02/070105

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2/2

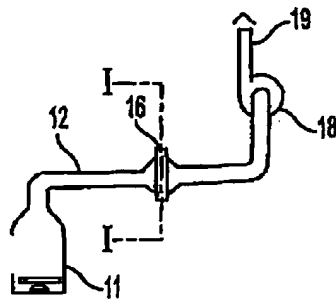


FIG. 2A

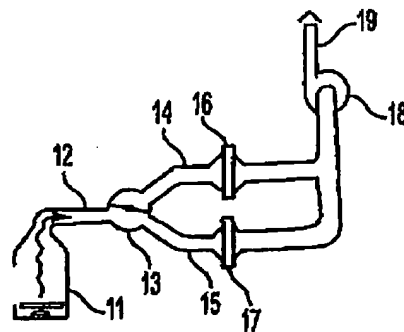


FIG. 2B

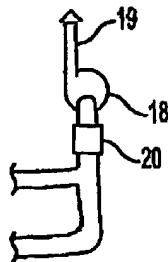


FIG. 2C

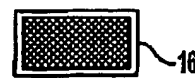


FIG. 2D

SUBSTITUTE SHEET (RULE 26)